ROMAN CONCRETE

(B45) What is Roman concrete and how did the development of this technique contribute to the creation of a new mode of space-making and architectural thinking? How did this architecture, with its technological underpinnings and utilitarian interests, help create an architectural aesthetics which bridged the realm between Greece and Rome?

Roman concrete (opus caementicium), like modern concrete, is an artificial building material composed of an aggregate, a binding agent, and water. Aggregate is essentially a filler, such as gravel, chunks of stone and rubble, broken bricks, etc. Binding agent is a substance which is mixed with the aggregate wet (water added) and solidifies when it dries, or "sets." Many materials, even mud, can be a binding agent, and used to make, what we generally call, mortar. Historically lime or gypsum, mixed with rubble stones, have been used as binding agents in making a strong mortar. Roman contribution to this basic structural mixture was the addition as primary binding agent pozzolona, a special volcanic dust found in central Italy. Pozzolona created an exceptionally strong bond with the aggregate. In most parts of the Roman world, where similar volcanic powders could not be found, local materials such as lime or gypsum were used as binding agents [N.B. the binding agent used in modern concrete is called "cement," or Portland cement. It is manufactured artificially using natural, earth substances. Modern concrete is stronger than Roman concrete mainly because it incorporates steel bars to build up tensile strength; technically, it is "reinforced concrete," or ferro-concrete. Romans did not use metal-reinforced concrete].

(B46) Concrete, as the Romans developed it, had some very definite technical and practical advantages over the traditional, and mainly Greek, methods of enclosing space by the use of cut-stone and post-and-beam structures. The advantages of opus caementicium can be summarized as follows: a) it was exceptionally strong and could span great distances when shaped into arches, vaults and domes; b) it had greater flexibility in molding space since concrete was virtually "poured" (or layered) into a formwork and took the shape of its container -- concrete is that sense is a "plastic" material; c) it did not requite special, skilled labor, therefore, it was cheaper; d) it was much faster to construct than laboriously cut ashlar masonry; e) since concrete-vaulted roofing was fireproof, unlike the wooden-beamed roofs of traditional systems, it was safer.

From the earliest days of the Republic, Romans took advantage of this method in the construction of foundations, terraces, and harbor structures (because concrete could set under water). It was a formidable tool of Roman engineering know-how. Yet, for all its advantages, concrete had one major defect: it was unsightly. Once the wooden formwork was removed, it showed an ugly surface. In the beginning, its use was mainly restricted to substructures where noone would see it. Practical-minded as the Romans were, they solved the aesthetic problem by covering, or surfacing, concrete by another material which they deemed visually more satisfactory.

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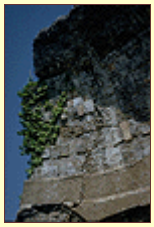

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(B47) In the late Republican period (starting ca. 200 B.C.), slabs of tufa (a soft, volcanic stone easily found in central Italy) were often chosen to face a core construction of concrete as in the circular temple (Temple "C") in Largo Argentina in Rome. Or, irregular shaped, fist-sized tufa blocks created a wall mosaic covering the concrete (opus incertum) **(B48)**. During the last century of the Republic and into the early empire, the favored method was to face concrete construction by regularized, diagonally arranged, square blocks of tufa (opus reticulatum), as we see in these examples from Hadrian's Villa at Tivoli **(B50, B51)**. These small, square blocks were shaped like cones, their pointed ends firmly embedded in concrete. By the early empire, the advantages of kiln-baked brick as facing had also been recognized although this system reached its greatest popularity in the 2nd-century **(B52, B53)**. In many instances, Romans, with their keen eclectic sensibilities, even mixed different materials for facing - opus incertum or opus reticulatum with brick, ashlar, and small stone-block construction. This popular and practical method, not surprisingly, was referred to as opus mixtum, as this fine example from Pompeii illustrates **(B48, B49)**.

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[A20]

All of these different facing materials were well bonded with the concrete core of the wall and they could be veneered over by still another, this time a more decorative material. This surface veneer was often stucco or plaster, molded, patterned and painted (sometimes to imitate blocks of marble). In exceptionally fine buildings, budgets allowing, marble incrustation was used as a luxury material par excellence, even incorporating a decorative use of the orders as applied on the wall in the form of pilasters or half-columns **(A20)**. One can see, and appreciate, how much greater an area Romans could surface with 0.5-1.0-inch thick plaques of marble than using solid blocks, as Greeks would have loved to do!

Whatever method the Romans used in facing concrete, and shaping it into powerful arches and lofty vaults, one should remember that underneath is the nearly indestructible mass of concrete providing structural integrity to the building, and holding it up. Even arches and vaults, which appear so deceptively like solid brick construction from the outside, once the surface is damaged (as in this examples of Several period warehouses from Ostia harbor) reveal that inside they are made of layers of concrete no different than any other part of the wall **(A1)**.

[A2]

[A3]

[A4]

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[A6]

Yet, Romans always retained a structural sense in using materials even when they applied them as veneer. Sometimes, they even chose to integrate structure and surface ornament, and exploited the polychromatic effects of natural materials without veneer. A wall in Ostia display the decorative effects of opus reticulatum in black and white blocks, and bands of red brick **(A2)**. Another, from a tomb, uses two-toned brick, stone, marble, and terracotta, all making a handsome polychromatic composition framing an arch **(A3)**. Contrasting coloristic use of two-toned, specially-manufactured bricks, red and creamy-buff, in pilasters, pilaster capitals, and entablature of a 2nd-century private tomb on Via Appia Antica, outside Rome, is one among the many demonstrating the extent brick came to be used as a sophisticated material in its own right **(A4, A5)**. Nor was this an isolated trend limited to the capital: the remarkable scalloped brickwork surfacing a small concrete dome in Nysa, Asia Minor (Turkey) is an instance of such sophistication available in the provinces, even though in this case, the brickwork is fully structural, not a facing for concrete **(A6)**.

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